

**Attachment OPT to the  
Memorandum of Understanding (LIGO-M050292-00-M)  
between the  
Caltech Relativity Theory Group (CaRT)  
and the  
Laser Interferometer Gravitational Wave Observatory (LIGO)  
August 15, 2005**

This Attachment OPT to the Memorandum of Understanding LIGO-M050292-00-M defines the role of the Caltech Relativity Theory Group (CaRT) as a Member of the LIGO Scientific Collaboration (LSC) and a member of the Optics Development Group (ODG). The period of performance for the activities in this Attachment is from August 15, 2005 to August 15, 2006.

1. Optics Development Group – The Optics Development Group (ODG) is the scientific collaboration for defining and developing improvements in optics for use in advanced subsystems for the initial LIGO interferometers or in entirely new advanced interferometers. MOU Attachments define the roles and responsibilities of groups in this development group.
2. During the period August 15, 2005 to August 15, 2006, the members of CaRT Group will participate in ODG in the following areas. *For background and details on most of these projects, see current and past CaRT Progress Reports and past MOUs.*
  - a) **Light scattering in the LIGO beam tubes and design of the baffles that control it:** K. Thorne and E. Flanagan [CURG; Cornell University] will complete their long paper on the theory of light scattering noise in beam tubes and its control by baffles with various shapes. They also will embark on writing a companion paper on beam-tube light-scattering noise for Advanced LIGO. As a foundation for this paper, they will update their 1995-96 computations making use of all available, relevant measurement data for beam-tube, baffle and mirror properties. Of particular concern will be the noise estimates for nearly concentric advanced-LIGO mirrors, which are expected to have larger microroughness than nearly flat mirrors. These noise estimates may lead to a necessity to place revised limits on the acceptable spectrum of mirror microroughness.
  - b) **Optimization of the Degeneracy of the Signal Recycling Cavity for Advanced LIGO:** Pan will continue his analysis of the optimization of the degeneracy of the signal recycling cavity for Advanced LIGO. In collaboration with Hiroaki Yamamoto and Phil Willems [LIGO Lab-Caltech], Pan will develop an FFT simulation code for the Advanced LIGO interferometer which will eventually provide more precise result on the optimal degeneracy. In collaboration with Willems, Pan will study possible modifications to the current design to achieve the optimal degeneracy.
  - c) **Influence of SR-Cavity Optical Losses on Noise Performance of Advanced LIGO:** Preliminary studies by Buonanno [UMd] and Chen [AEI-GEO] have shown that optical losses in the signal-recycling [SR] cavity of advanced LIGO can significantly degrade the performance of narrow-banded configurations. Pan, with Buonanno and Chen, will

carry out a detailed theoretical investigation of this effect. They will explore the extent to which, by changing to a 4-kilometer-long SR cavity, this problem can be alleviated.

- d) **Duality Relations for Optical Cavities with Nearly Concentric and Nearly Flat Mirrors:** Savov, with Chen [AEI-GEO] and J. Agresti and E. D'Ambrosio [LIGO-Lab Caltech] will complete and submit for publication their paper presenting analytic proofs of the duality relation between nearly spherical and nearly concentric optical cavities, which Savov discovered numerically.
  - e) **Reshaping Mirrors to Reduce the Strength of the Parametric Instability:** Savov and Thorne will attempt to find new mirror shapes, and corresponding fundamental (TEM00) mode profiles, for which the number of parasitic Stokes modes with low diffraction losses is substantially lower than in the case of spherical mirrors and their Gaussian mode profiles. (This will substantially reduce the strength of the Braginsky-Strigin-Vyatchanin parametric instability.) They will attempt, simultaneously, to guarantee that the TEM00 mode has a near Mesa-beam shape so as to reduce thermal noise. See CaRT Progress report for background on this project.
3. Resource Sharing: The LIGO Laboratory will contribute resources including allocation of appropriate scientific and engineering personnel, research facilities and funding in support of the effort in Item No. 2, as indicated below.
- a) Research accommodations for CaRT group members while on LIGO research assignment at any LIGO Laboratory site,
  - b) Access to LIGO data through established LSC channels in support of this work.
4. Coordination and Reporting – CaRT Group will perform this research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular activities described in Item 2 will be carried out within the Optics Development Working Group of the LSC. Coordination will include keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.

In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time. This Attachment will be updated at least annually with a plan of activities for the succeeding on-year period. These documents will be due one month before the close of the period of performance under this Attachment.

Approved:

---

Barry Barish  
LIGO Laboratory Director

---

Kip S. Thorne  
CaRT Principal Investigator

---

Peter Saulson  
LSC Spokesperson

---

David Reitze  
ODG Leader